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GEO-ELECTRIC ASSESSMENT OF GROUNDWATER POTENTIALS IN COMPLEX BASEMENT TERRAIN: CASE STUDY OF COLLEGE OF ARTS AND SOCIAL SCIENCES, KADUNA POLYTECHNIC BYE-PASS CAMPUS, NORTHWESTERN NIGERIA

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ABSTRACT
A geo-electrical investigation to explore best sites for groundwater was carried out at College of arts and social sciences, Kaduna Polytechnic Bye-pass campus, Kaduna State, Nigeria. Nine Schlumberger Vertical Electrical Sounding (VES) points were established and the resistivity interpretation revealed maximum of four geologic layers. Fields data were interpreted using both curve matching techniques and computer based iteration using the IPWIN (Version 3.0.1) programme. The results of the investigations are presented as resistivity sections and subsurface contour sections from the interpretation of the sounding curves. VES points 7 and 8 have the highest depths to the bottom of extensive weathered basement which have corresponding thicknesses of 62 m and 78 m. They are therefore recommended as the best points for sinking boreholes as they have complementary properties for higher yield.

KEYWORDS: Schlumberger, electrical resistivity, resistivity cross-section, isopach

INTRODUCTION

The research site, College of Arts and Social Sciences (CASS), Kaduna Polytechnic Bye-pass campus, is located at the southern part of Kaduna metropolis that approximately lies on 7^0 26' East longitudes and 10^0 27' North latitudes on the national grid. The area is connected to some settlement at the northern part; prominent among them are Television village, Unguwar Romi, Anguwan Muazu, Kakuri and Nasarawa villages, all of which are located in Kaduna Township that fall in the North-Western geopolitical zone of Nigeria. The land undulates within the range of 609.6 m and 670.5 m above sea level. The undulating gives rise to Kaduna River, running from the north-east to the south-west of the state. The river valley occupies the lower relief of the site and is between 579.3 m and 609.7 m (Olugboye, 1975).The present study area is underlain by Pre-Cambrian rocks. Here groundwater occurs either in the weathered mantle or in the joint and fracture systems in the unweathered rocks (Dan-Hassan and Olorunfemi, 1999; Olorunfemi and Olorunniwa, 1985; Olayinka and Olorunfemi, 1992). The highest groundwater yield in Basement terrain is found in areas where thick overburden overlies fractured zones (Olorunniwa and Olorunfemi, 1987). These zones are often characterized by relatively low resistivity. With the increasing high water demand for domestic, agricultural and industrial purposes, the urgent need to develop groundwater resources to the maximum possible extent has recently gained importance. The successful exploration of Basement terrain requires a proper understanding of its geo-hydrological characteristics. This is particularly important in view of the discontinuous (localized) nature of Basement aquifers (Dan-Hassan and Olorunfemi, 1999; Satpathy and Kanungo, 1976). Drilling programmes for groundwater development in areas of Basement terrain are generally preceded by detailed hydro-geophysical investigations. The study area (Fig 1) has a typical savannah climate with distinct wet and dry seasons. The rainy season extends from March/April to October /November and a dry season between December and March. Average annual rainfall for Kaduna is 1054 mm (Eduvie, 1998). Rainfall generally reaches a peak in August. Temperatures vary between less than 15 ^oC around December/January and 32 ^oC in March/April. Vegetation consists of broad-leaved Savannah woodland which, when well developed, may attain heights of about 15m, and may be dense enough to suppress the growth of grasses. The prominent hilly features in the area are inselbergs and whalebacks which belong to the category of residual hills commonly associated with massive granite bodies (McCurry, 1976).

The present study applied the electrical resistivity method of geophysical investigation to delineate the different subsurface geo-electric layers, the aquifer units and their characteristics in the College of Arts and Social Sciences (CASS), Kaduna Polytechnic Bye-pass Campus, Chikun local government area, Kaduna State, Nigeria.

The objective is to locate areas to drill wells for the exploration of groundwater for the provision of portable water for the local community.

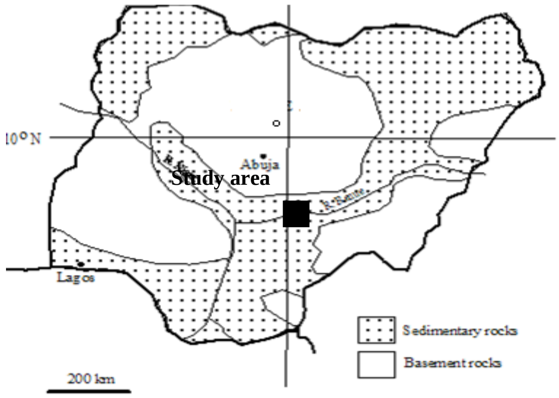

Fig.1: Location and Geology of the Study area.

MATERIAL AND METHODS

Electrical Resistivity measurement

The electrical resistivity survey was performed with an ABEM Terrameter SAS 300C. In the present study, the electrical array used was the 4-electrode Schlumberger configuration (Fig 2) employing the Vertical Electrical Sounding (VES). The theory of the electrical resistivity survey is well documented in standard texts such as Koefoed (1979), Keller and Frischknecht(1966) and Telford et al (1990).

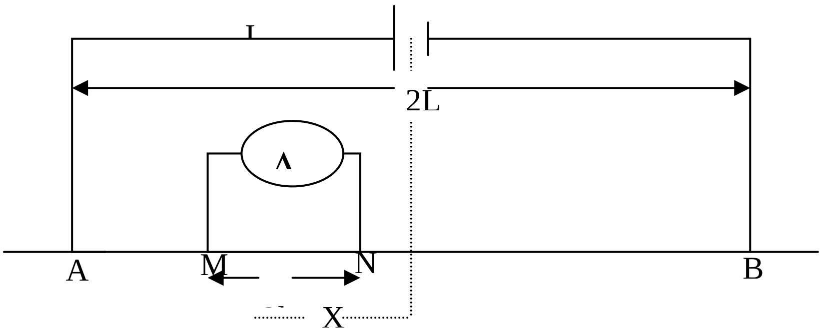

Fig.2: Schlumberger electrode configuration.

Geo-electric data are usually expressed as:

$$\rho_a = \frac{\Delta V}{I} K \quad (1)$$

Where ΔV is the measured potential, I the transmitted current and K the geometric factor expressed as:

$$K = 2\pi \left[\frac{1}{|r_A - r_M|} - \frac{1}{|r_A - r_N|} - \frac{1}{|r_B - r_M|} + \frac{1}{|r_B - r_N|} \right] \quad (2)$$

In equation (2), r_A and r_B are positions of the current electrodes and r_M and r_N are positions of the potential electrodes. In the schlumberger configuration (Fig 2), the distance AB (2L) between the current electrodes is large compared with the distance MN (2l) between the potential electrodes. The apparent resistivity reduces to the following:

$$\rho_a = \frac{\pi (L^2 - X^2)^2}{2l(L^2 + X^2)} \frac{\Delta V}{I} \quad (3)$$

When used symmetrically, X = 0, Eqn. (3) becomes

$$\rho_a = \frac{\pi L^2}{2l}\frac{\Delta V}{I} \tag{4}$$

For the present survey, a maximum of AB of 200 m and MN of 3 m were occupied for effective probe of the basement layer. A detailed location map of the Geo-electrical survey is shown in Fig. 3.

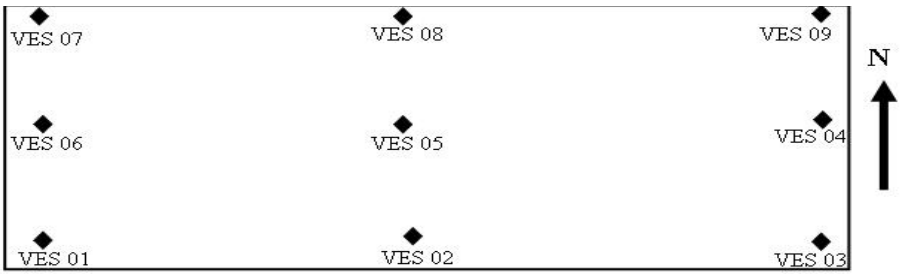

Fig.3: Generalized map of the Geoelectrical Survey.

Data Interpretation

Fields data were interpreted using both curve matching techniques and computer based iteration using the IPWIN (Version 3.0.1) programme developed by the Geophysics Group, Moscow state university. Data were interpreted in terms of three and four layers. Figure 4 shows a typical VES curve. Logs within Kaduna metropolis (Fig 5) were considered in driving the general geologic sections in the study area. The VES data were then plotted as resistivity cross-sections in order to look at the distribution of the geo-electric layer hosting the water bearing zones (Figs 6, 7 and 8).

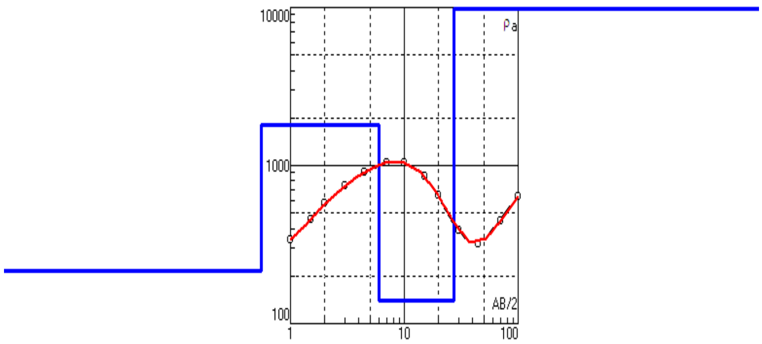

Fig.4: Typical VES curves.

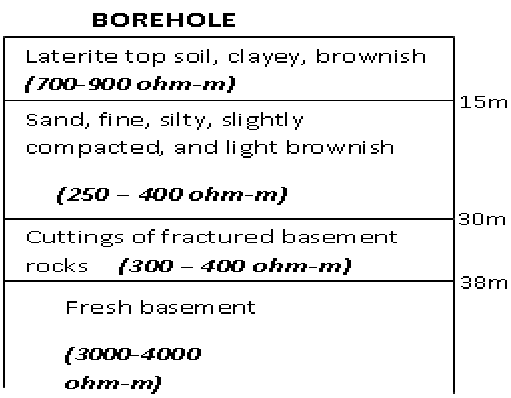

Fig.5: Borehole lithology and interpretation modified from Aboh (2001).

RESULTS AND DISCUSSION

Interpretation of VES 01-03

Figure 6 shows the resistivity cross-section constructed for VES points 01 – 03. The figure shows a 4-layer (KH type) for all the sounding points. The topsoil is characterized by resistivity values between 220 ohm-m and 400 ohm-m and thickness values between 0.6 m and 2.7 m. Going by the characteristic resistivity values for the earth materials found within the study area and the lithologies of the borehole logs (Fig.5), the topsoil is diagnosed to be dry sand soil. The second layer with higher resistivity value of between 680 ohm-m and 1800 ohm-m typifies laterite. The thickness of this layer ranges from 6 m to 21 m. Beneath the second layer, the resistivity cross-section reflects a layer identified as the aquifer unit characterized by resistivity values between 110 ohm-m and 140 ohm-m. The thickness of this layer is appreciable, ranging from 27 m to 50 m, diagnostic of extensive weathered bedrock. The fourth Geoelectrical layer with infinite thickness has resistivity of between 12000 ohm-m and 35000 ohm-m. This high resistivity of the fourth layer is typical of fresh granitic rock.

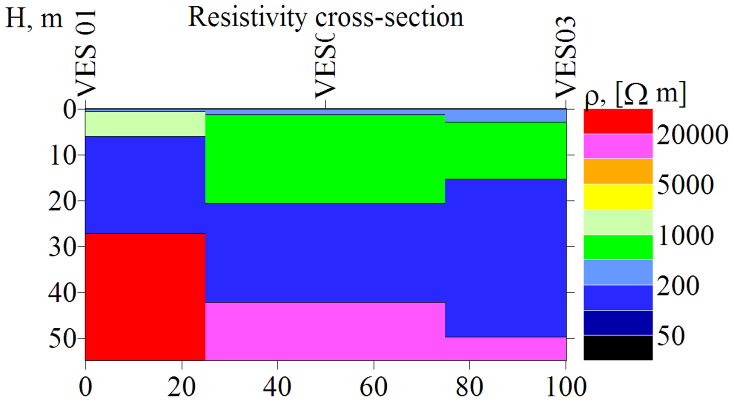

Fig.6: Resistivity cross-section for VES 01- 03

Interpretation of VES 04 - 06

The resistivity cross-section for VES points 04 to 06 is shown in Figure 7. The result of the sounding curves show generally a 4 Geoelectrical layer (KH type) except at VES 06 which delineate a 3 layer (H type). The topsoil with resistivity varying between 500 ohm-m and 900 ohm-m is interpreted as lateric soil. This layer has an average thickness of 3 m. The second layer resistivity varies from 150 ohm-m at VES 06 to 620 ohm-m at VES 5. The thickness varies from 12 m to 50 m. This layer typified the clayey sand unit at VES points 04 and 05 while the Geoelectrical layer at VES 06 is diagnostic of the weathered basement reflecting the aquifer unit. The third layer beneath VES 04 and 05 with resistivity values of between 40 ohm-m and 60 ohm-m is characteristic of in-situ weathered clay material. The thickness of these VES points varies from 12 m to 21 m. The third layer beneath VES 06 identified as the fresh basement has a resistivity value of 3500 ohm-m and infinite thickness. The fourth layer for VES points 04 and 05 with infinite thickness and resistivity values between 4000 ohm-m and 10000 ohm-m reflects the fresh basement.

Interpretation of VES 07 - 09

The resistivity cross-section for VES points 07 to 09 (Fig.8) shows a 4-layer (KH type). The topsoil with an average thickness of 2 m has resistivity values ranging from 400 ohm-m to 1120 ohm-m. These resistivity values typifies lateritic layer. The second layer with resistivity ranging from 300 ohm-m to 800 ohm-m is interpreted as the clayey sand unit. The thickness varies from 5 m to 12 m. The weathered basement layer composed of sand/gravel materials is the third layer beneath these VES points. The resistivity of this layer varies between 160 ohm-m to 400 ohm-m. The thickness is quite appreciable, varying from 36 m to 78 m. The fourth layer has resistivity varying from 1900 ohm-m to 8,500 ohm-m. The resistivity values of 1900 ohm-m and 2300 ohm-m beneath VES 07 and VES 08 respectively which are the lowest obtained in the study area indicate fracturing within the fresh basement rock considering the thickness beneath these VES points.

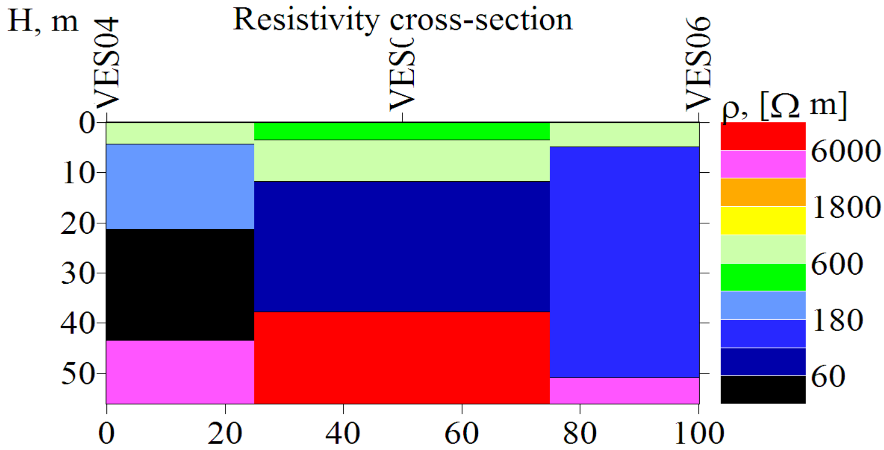

Fig.7: Resistivity cross-section for VES 04-06

The Isopach map of the overburden

The thicknesses of the overburden (depth to bedrock) beneath the sounding points were contoured and plotted using Surfer 8 as shown in Fig.9.The depth to bedrock varies from 27 m to 83 m. The Isopach map reveals increasing thickness towards the northern section (> 50 m) which correspond to basement depression while the south-western part with thickness less than 40 m corresponds to basement high. Generally, areas with thick weathering and low percentage of clay are known to have high groundwater potential in the basement complex (Okuhe and Olorunfemi, 1991).

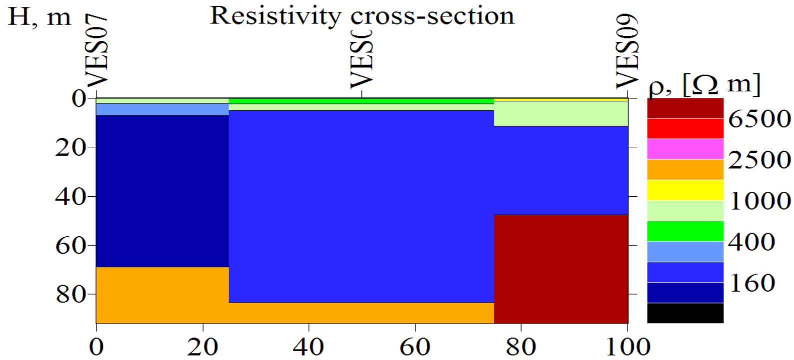

Fig.8: Resistivity cross-section for VES 07 – 09.

The Iso-resistivity map of the weathered basement layer

Figure 10 shows the resistivity map of the weathered basement (water bearing zone) with contour interval of 5 ohm-m. The map shows resistivity values less than 100 ohm-m beneath VES 04 and 05 which is attributed to in-situ weathered clay. The map further shows resistivity varies between 120 ohm-m and 190 ohm–m around VES 01, 06 07, 08 and 09 resulting from in-situ chemical weathering producing sands and gravel materials (Olasehinde and Raji, 2007). The VES points (07 and 08) which correspond to the thickest weathered points (Fig.9) is indicative of bedrock fracturing and are priority zones for water development in the study area.

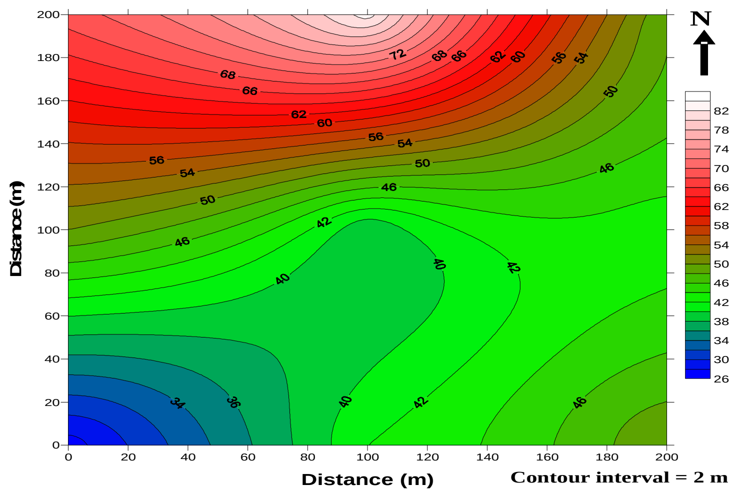

Fig.9 Isopach map of overburden

CONCLUSION

The interpretation of the VES data has enabled the derivation of four geologic units. The uppermost layer consists of laterite and sand. This formation is followed in succession by clayey sand, weathered basement, fractured/fresh basement. The Isopach map of the overburden in the study area varies from 27 m to 83 m while the aquifer resistivity ranges from 40 ohm-m to 192 ohm-m. Areas with thick overburden (>50m) correspond to basement depression while the zones with relatively thin weathering correspond to basement highs. The materials of the rocks where fracturing and severe weathering occurred (VES 07 and 08) are priority zones for groundwater exploitation.

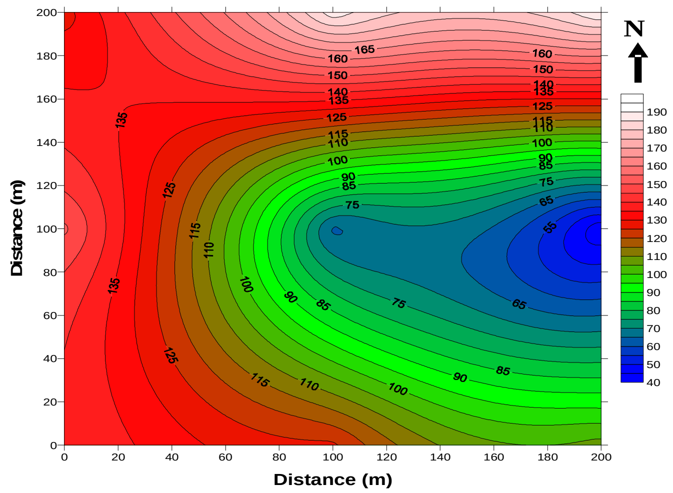

Fig.10: Weathered Basement map

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